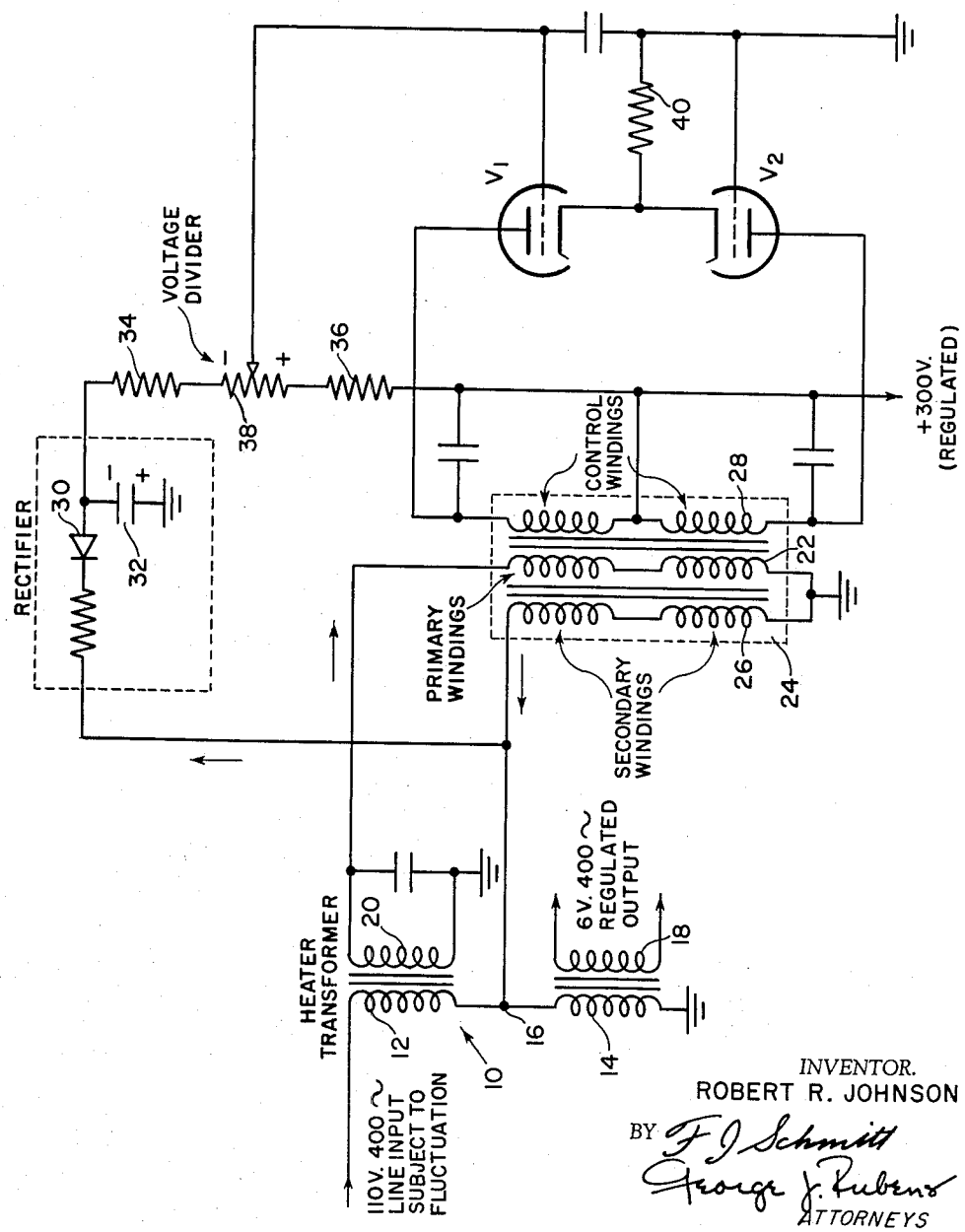
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VOLTAGE REGULATING SYSTEM

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VOLTAGE REGULATING SYSTEM

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The present invention relates in general to voltage regulators, and more particularly to a regulating device, incorporating a magnetic amplifier, which is effective to develop an essentially constant output potential regardless of random fluctuations in supply line voltage.

In some types of electronic equipment, it is highly desirable to have available an unvarying voltage which can be applied, for example, to a vacuum tube heater circuit in cases where signal ouput from the apparatus is critically dependent upon the avoidance of variations in cathode emission resulting from random heater voltage fluctuations. Such heater voltage irregularities can change the gain of the tubes, or bring about a shift in the point at which they operate on their characteristic curves. Although equipment of the nature referred to is frequently provided with a regulated power supply for the tube plates or anodes, it is not usually practicable to "bleed" energy from this source for heater purposes since the complexity and/or weight of such an anode power supply is markedly increased by the heavy current drain thus imposed thereon.

The present invention overcomes this difficulty by utilizing energy direct from the power line, and then provides means to compensate for any fluctuations in line supply. This means includes a magnetic amplifier controlled from a pair of balanced vacuum tubes, the latter being biased in accordance with the algebraic sum of the voltages respectively derived from the regulated power supply and from the power line input. Any change in the value of this bias, resulting from a power line variation, unbalances the vacuum tubes, and results in the development of an electromagnetic flux to partially saturate the core of the magnetic amplifier. This has the effect of altering the value of the amplifier's output as compared to the input thereto, and such output, in proper polarity and phase, is fed back to the heater transformer to neutralize the power line fluctuations.

One object of the present invention, therefore, is to provide an improved form of electronic voltage regulator acting to compensate for random irregularities in energy received from a supply line.

Another object of the invention is to provide a voltage regulator, of the type described, incorporating a magnetic amplifier which acts to develop a control variation of such polarity and phase as to neutralize input fluctuations which would otherwise appear in the output of the apparatus.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawing, the single figure of which is a schematic representation of a voltage regulating circuit embodying a preferred form of the present invention.

Referring now to the drawing, there is illustrated a transformer, generally identified by the reference numeral **10**, which acts in the example chosen to step down a standard A.-C. line input of 110–120 volts to approximately 6 volts for utilization by some such equipment as the heaters of a series of vacuum tube amplifiers in a radar detection system or other similar receiver of radiant energy. The transformer **10** has two primary windings **12** and **14** between which a connection is made at **16** for

purposes to be later described. The line input, at approximately 110 volts, is applied to winding **12**, this input wave having a frequency which may, for example, be in the neighborhood of 400 cycles per second. As is often the case with energy taken directly from a general supply source, random fluctuations may be present which normally are passed into the transformer output circuit and are thus received by the utilization apparatus.

In the system of the drawing, such a utilization apparatus (not shown) is connected to one secondary transformer winding **18**. The latter is magnetically coupled, as illustrated, to the primary winding **14**. The relative number of turns of each of these windings is so chosen that the value of the output energy is approximately 5.8 volts, although this figure is obviously predetermined in accordance with the particular operating requirements of the utilization equipment. Another secondary transformer winding **20** is coupled to the primary winding **12**. From winding **20** energy is supplied to the series-connected primary windings **22** of a saturable-core transformer acting as a magnetic amplifier. This latter is generally identified in the drawings by the reference numeral **24**.

The saturable-core transformer **24** includes, in addition to the previously-mentioned primary windings **22**, a pair of series-connected secondary windings **26** and a further pair of series-connected control windings **28**. All three windings **22**, **26**, and **28** of transformer **24** are disposed in inductive relationship to one another, and, in accordance with the well-known operating characteristics of such devices, the transfer of energy between the primary and secondary windings **22** and **26**, respectively, is a function of the degree of saturation of the transformer core, and the latter in turn is dependent upon the density of the magnetic flux developed by current flow in the control windings **28**. Such flux tends to saturate the transformer core and reduce the output of the transformer. Expressed differently, the output of the unit **24**, as derived from windings **26**, is a function both of the energy supplied to the primary windings **22** and the flux developed by current flow in the control windings **28**, these two factors being broadly effective in an opposite sense in that an increase in the latter tends to reduce the electromagnetic coupling between the primary and secondary windings **22** and **26**, respectively, and hence precludes an increase in input energy to windings **22** from being proportionally transferred to the transformer output.

The voltage appearing at point **16** is rectified by a crystal diode **30**. This diode is electrically connected so that the voltage developed on its associated storage capacitor **32** is of negative polarity, with the circuit constants being so chosen that fluctuations in line voltage appearing at point **16** develop corresponding changes in the value of the energy stored by the capacitor. Such energy is applied to one terminal of a series-connected voltage divider network consisting of two resistors **34** and **36** and a potentiometer **38**. The remaining terminal of the voltage divider is connected to a stable source of energy such as that which supplies operating potential to the anodes of the electron discharge tubes of the receiver. It is essential that such source be regulated, or otherwise free from fluctuations, throughout the interval during which described system is to be effective. The value of this potential source connected to resistor **36** (approximately 300 volts in the example given) is such that the movable contact of potentiometer **38** can be manually adjusted close to a point of nominally zero voltage, based upon the magnitude of the energy stored in capacitor **30** under normal line input conditions. This is accomplished when the positive potential from the regulated source approximately equals (at the location of the movable potentiometer terminal)

the negative voltage developed on capacitor **32**, the value of the resistor **36** being sufficiently greater than the value of resistor **34** to compensate for the unequal magnitudes of the respective voltage sources to which they are connected.

A pair of vacuum tube triodes V_1 and V_2 are arranged in balanced relationship, with the cathodes of the tubes being directly connected together and thence to ground through a common resistor **40**. The anode of triode V_1 is supplied with energy from the regulated operating potential source through one of the control windings **28** of the magnetic amplifier **24**, while the anode of triode V_2 is similarly supplied through the remaining control winding, as illustrated in the drawing. The control electrode of triode V_2 is grounded directly, while that of triode V_1 is connected to the movable contact of potentiometer **38**.

In describing the operation of the illustrated circuit, it will first be assumed that the line input is of normal value, thus yielding a desired constant voltage output from the transformer secondary winding **18**. Under such conditions, the cylically varying voltage appearing at point **16** is rectified by the diode **30** to develop on capacitor **32** a negative voltage of such magnitude as to approximately balance, at the movable contact of potentiometer **38**, the positive potential obtained from the regulated source connected to resistor **36**. This is equivalent to stating that the potential on the control electrode of triode V_1 approximates zero volts. Since the potential on the control electrode of triode V_2 is always at zero volts (ground), the two tubes are close to being in balance, and conduct almost equally to cause nearly equal currents to flow through the two control windings **28** of the magnetic amplifier **24**. These two currents are in such directions as to oppose one another, however, and hence little resultant electromagnetic flux is produced in the transformer core and only slight saturation of the latter occurs. The input energy, as it appears across the secondary winding **20** of the heater transformer **10**, is electromagnetically transferred between the primary and secondary windings **22** and **26** of the magnetic amplifier **24** and fed back to the point **16** so as to maintain a predetermined voltage drop across winding **14**.

Now, however, assume that an undesired fluctuation occurs in the line supply, and that the voltage appearing at point **16** rises momentarily as a result thereof. Nominally this would cause a corresponding increase in the output energy derived from the transformer secondary winding **18**. However, when such a rise occurs, the unidirectional voltage developed on capacitor **32** also arises, and hence the potentiometer voltage at its movable contact increases negatively. This increased negative voltage, applied to the control electrode of tube V_1, decreases the conductivity of such tube, while the conductivity of tube V_2 remains as before. Accordingly, more current flows through that portion of winding **28** of amplifier **24** associated with tube V_2 than through that winding portion associated with tube V_1. A stronger resultant electromagnetic flux is developed in the amplifier to at least partially saturate the core thereof and thereby modify the energy transfer from primary windings **22** to secondary windings **26**. The latter are so wound that the phase of the energy fed back to point **16** neutralizes, or compensates for, the increase in line voltage, and hence the drop across transformer winding **14** remains constant regardless of the input fluctuation from which the regulatory effect was derived.

It is desirable to have the voltage on the control electrode of triode V_1 only approximate zero in order to allow for fluctuations of the line voltage in a negative as well as in a positive direction. Otherwise tube V_1 would be in complete balance with triode V_2 under normal voltage conditions, and momentary drops in line voltage would place a positive potential on the control electrode of the tube. Its conductive status at such times would therefore not be such as to yield the desired compensating action.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

I claim:

1. In a regulatory circuit for developing a substantially constant output voltage of relatively low amplitude from a cyclically varying higher-amplitude bidirectional line input which is subject to random fluctuations from a nominal value: the combination of a transformer having at least one primary winding to which input energy from said line is applied, a secondary winding for developing a regulatory control voltage, and a step down secondary winding for deriving said relatively low-amplitude output voltage; a saturable-core magnetic amplifier having primary, secondary, and control windings; a connection between the regulatory control winding of said transformer and the primary winding of said magnetic amplifier; a feedback connection from the secondary winding of said magnetic amplifier to a point on the primary winding of said magnetic amplifier; a feedback connection from the said transformer; means for rectifying at least a portion of the cyclically-varying input energy; a source of constant potential of opposite polarity to that developed by said rectifying means; a voltage divider connected between the constant potential source and the output of said rectifying means; circuit means responsive to changes in the voltage appearing at a nominally balanced point on said voltage divider to correspondingly vary the amount of current flowing throughout the control windings of said magnetic amplifier and thereby alter the degree of saturation of said core and hence the transfer of energy between the pirmary and secondary windings of said amplifier; and means for applying the energy so transferred between the primary and secondary windings of said magnetic amplifier to stabilize the amount of inductive coupling between the primary and step down secondary windings of said transformer.

2. A regulatory circuit according to claim 1 in which the circuit means responsive to changes in the voltage appearing at a balanced point on said voltage divider includes a pair of balanced electron discharge devices, one of said electron discharge devices having a control electrode connected to a point of constant potential and the other of said electron discharge devices having a control electrode connected to the nominally balanced point on said voltage divider.

References Cited in the file of this patent

UNITED STATES PATENTS

1,894,133	Thompson	Jan. 10, 1933
1,997,657	Schmutz	Apr. 16, 1935
2,743,785	Lee	May 1, 1956
2,883,608	Smith	Apr. 21, 1959
2,920,264	Wintrode	Jan. 5, 1960